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ABSTRACT

This discussion of a new computer-based medium describes microcomputer (MC) painting and its principal tool, the MC paintbrush, and explores their potential roles in mathematics, computer science, and art education in secondary schools. This paper describes the school computer, discusses capabilities of MC painting, explains how MC painting is done and what the computer does, argues for classroom use of the school computer, and discusses the meaning of literacy in mathematics, computers, and art. (Author/JD)

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A Multi-Purpose Educational Medium---MC Painting

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Preface

We wish, through this paper, to introduce MC painting to teachers before we have taught with it extensively ourselves, for it is the teachers who will be the ones to find the appropriate educational niches for this new medium that "anyone can use".

The larger part of our experience with MC painting is in developing it and trying it out as an art medium with our colleagues, and the smaller part is in teaching students. We feel however that MC painting, on the basis of theoretical arguments as well as on the basis of our experience, will be a useful medium for students and teachers in many areas, and especially in mathematics, computer science and art. The authors' experience in appreciating, teaching and doing in these three areas stimulated their development of MC painting and supports their belief in its relevance to all three subjects.

We therefore discuss the three areas in parallel throughout the paper - there is something in each section for teachers of mathematics, of computer science or of art.

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A Multi-Purpose Educational Medium - MC* Painting

Melanie Zibit and Bruce Hicks

SUMMARY

A new means of curriculum integration has become feasible - MC painting, a computer-based medium. It can provide the mathematics or computer science as well as the art curriculum with exciting new means of learning and experiencing. Moreover the medium is feasible for schools to use because of the availability of small, inexpensive computers (microcomputers) that anyone can use to "paint" on a color TV screen.

1. Introduction

We shall discuss the new medium, MC* painting, and its principal tool, the MC* paint brush, and explore their potential roles in mathematics, computer science and art education in the schools.

The curriculum integration provided by MC painting can occur in several ways. This new medium can be used to illustrate topics the students are already studying. It acts as a sounding board on which they synthesize the concepts of mathematics and computers, with the embellishment of immediate color in their results. It introduces the student to the contemporary uses of computers in society, and, indeed, acquaints the student with this tool of the future while supplying a rich source of enjoyment. It combines the visual elements of color and pattern to stimulate the interplay of perception, cognition, affect and motor activities. Thus, the art aspects of the MC painting adapt themselves to almost any subject as they add visual perceptions to abstract learning. MC painting can help anyone understand computers and enjoy working with them.

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*MC = microcomputer

Our discussion contains an introduction to the school computer (Section 2), followed by a few examples of MC paintings and what they can illustrate in the three areas, mathematics, computer science and art education (Section 3). The details on how to use the MC painting (for teacher or student) are described in Section 4, exemplifying the variety of ways in which a computer can serve individuals. Section 5 describes the computer's roles in MC painting. Section 6 points toward the possibilities of having this new educational medium in your school. The last section describes the use of a school computer as a multi-purpose tool leading to a broad literacy, that is a mutual appreciation by the different computer users of all of its applications.

We believe that MC painting can be an enjoyable and colorful means of learning about mathematics, about computers or about art through direct, interactive experience and at any grade level. We hope that this introduction to the new educational medium will induce many teachers and students to explore its rich potential.

2. The School Computer*

What we mean by the school computer is a device that anyone, student, teacher or administrator, can use easily for various jobs that only a computer can do, from educational games to business calculations, from instruction to keeping class records. Here the particular subject of our discussion is its application in mathematics, computer science and art education.

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*An important characteristic of the school computer is its low cost - as little as $1500, and since it is used by many individuals for a variety of purposes this cost is not charged just to one individual or one purpose. It is only those computers that are easy to use, expensive and versatile enough to do the MC painting that we shall call school computers, and it is primarily these computers that we discuss in this paper.

Microcomputers (one kind of small computer) costing less than $600 are made by several companies and are already winning a place as "home/school computers" or "personal computers." To have the advantages of MC painting as well as those of the home/school computers requires, at present, the larger investment.

A teacher has described well (reference 1) the resources that a school computer can bring to the classroom.

> "I believe that diversity is an important key to the success of microcomputers in the classroom. Computers are often visualized as huge, grey boxes, useful primarily for esoteric number-crunching, delicate and complex, understandable only to an elite few. A classroom microcomputer making music, generating televised art, or playing Star Trek is the antithesis of this vision. It opens to all students the magic and promise of computer power at their fingertips."

Such computers can serve mathematics and computer science teachers and the art teacher equally well - serve them and also their students.*

What tasks does the computer do and how does it do them? The computer accepts instructions given by the user in simple ways, then follows those instructions. For example, the art teacher asks to look at the picture that was made by MC painting yesterday by a student. It is then displayed on the color TV screen. Or a math student calls on the computer for special calculations that illustrate a mathematics concept, like intersection of sets. Or the computer science student can "write a program" to tell the computer how to do a certain task he has defined carefully.

How does it do these and other tasks? The computer simply follows (fast and reliably) the detailed instruction it has been given. A set of these detailed instructions is a computer program.

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*We note that the computer and the TV display can be used either by individual students or for a group of students, as in a classroom. And the MC painting we are discussing in later sections is equally useful for the individual or for the group because of the direct impact of the color pictures, whatever application is being made of them, and because there is no fine detail in the pictures that would make group viewing difficult at classroom distances from the TV.

Every computer, not just the school computer, uses programs to do its work. Some of these programs can be bought or copied, and others, often the most important ones, are written in each school, by teachers and students, for their own particular purposes. It is unnecessary and not as effective to depend only upon outside sources for programs for school or home use.*

The students' role in writing programs for the computer in art or mathematics or computer science is an important and essential step in learning as we shall discuss in a later section.

3. Examples of MC Painting-The Multi-Purpose Educational Medium

Anyone can do printing on a color TV screen, and it is fun!

The mathematics student can study various topics, depending on his grade level, for example, numeration, length, area and symmetry properties of two dimensional figures. The computer science and electronics student can come to understand that the picture on the TV screen is being continuously transferred ("broadcast") to the TV set from a specific part of the computer's memory and under the control of the computer that is, in turn, being controlled by the user. The art student sees examples of line, balance and contrasting colors. These are a few of the topics illustrated by almost any MC painting after it has been created-and there are more than $10^{4,000}$ such pictures!

Let's look at individual pictures created with this new medium that illustrate a few of its educational applications at many grade levels. Further applications are given in later sections. The examples we show first are of most interest to art teachers although containing some elements relevant to mathematics and computer science teaching.

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*Strong evidence for the feasibility of this "write your own programs" approach is given by the work of Goddard (References 2, 3 and 4) and many articles in such magazines as Calculators/Computers.

Figure 1 (in black and white) shows some of the variety of brush and line patterns that can easily be produced in MC painting.

Figure 2* (in four colors) was made rather rapidly to express on the color TV screen the artist's feelings and sense of composition.

Figures 3a and 3b* are expressive in a different way, with more conscious control of the medium, as the line-drawing facility within MC painting was used to produce the simple architecture of Figure 3a (in five colors) and the "hard edge" painting in Figure 3b (in five colors).

Before continuing our discussion of examples of MC painting and their uses we must remark on the importance of color. MC painting provides 15 or 16 different colors. Color adds another dimension of perception and experience and excitement to the MC painting, no matter what the field of application. The significance of color can be suggested by the black and white figures in this report, but not fully appreciated. One of many examples: the mathematical topic of permutations can be strikingly represented in color.

We have so far considered a few individual MC paintings as examples, but there is a much richer source of educational applications of the medium in the several educational fields-that is the operations, the actions that produce the paintings or (always visibly) change them. These operations include hand movements, (controlling joystick, buttons or keys) mathematical calculations, programming "procedures" and algorithms, and the modes of action of the computer system itself.

Each tool in the medium and each corresponding operation is useful at all educational levels, but of course must be exploited appropriately at each level. As students and teachers themselves make vivid pictures their

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*The diagonal bands in many of the figures were produced by the camera's focal plane shutter.

interest in the various topics being studied and illustrated via the MC painting will be enhanced by their direct interaction with this versatile and exciting medium. They really become part of the medium!

They also can follow a process of discovery; what is happening? What regularities are there? Can I explain them? Has my art work expressed me and my feelings? How should I change it to make it a more satisfying expression of me?

Let's consider, then, some of the topics illustrated by making an MC painting* rather than just by looking at it.

The elementary arithmetic student can actively count by moving small squares from one part of the screen to another, in precise analogy to doing it "by hand" with real objects on a table. But the objects of different shapes and colors here can be created at will, and easily, by the student or teacher, to give variety and a basis for generalization. For example, as shown in Figures 4a,b, the student can move all the most symmetric objects on screen to the left and others to the right and then count the number in each subset.

At other levels, the mathematics student can produce examples of line segments, scales and rectangular Cartesian coordinates, discrete approximations to continuous curves, and, in chatting with the computer science student (informal interchange between students around a computer is often an effective educational tool) can appreciate that the MC painting system is performing a one-one mapping from computer memory to the TV screen.

Figures 5a-f illustrate for the mathematics student a rather different operation-the results of cutting and shuffling cards, which involves a number of logical concepts in mathematics as well as introducing the concept of a cyclic group.

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*The reader may find it advantageous to reread this section after studying Section 4.

The bottom half of Figure 5a shows two decks* side by side, of 32 cards each, the white and black cards alternating. If we shuffle and cut exactly then we get what is shown in the bottom half of Figure 5b, corresponding to one transformation carried out by the microcomputer. Notice that the white cards are now in pairs and also the black cards are in pairs, that is, the white and black rectangles are twice as thick as in Figure 5a. We shuffle and cut (or transform) again, and the cards are now in groups of four, as shown in Figure 5c. Further transformations lead to Figures 5d, e and f, and the cards are now separated into a black deck and a white deck. We make one more shuffle and cut (transformation), and we get Figure 5a again, that is, six transformations, for this size of deck, leads back to the original arrangement of cards!

The upper half of each figure shows the same process, but now each card is marked - a white spot on each black card and a black spot on each white card - and there are narrow, vertical partitions at each end of each card deck so that the details of the shuffling and cutting can be studied. Notice that the transformations change the black and white coloring of the partitions but not their position.

We developed this transformation in order to solve a technical computer problem in the MC painting, that is, the origin of the transformation lay in computer design and utilization. But the same transformation exhibits a process of interest in mathematics teaching because it illustrates transformations and "groups", the one here being a cyclic group, and also produces designs of some artistic interest -- another example of outcomes of MC painting that have interdisciplinary interest.

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*We must imagine a vertical partition, not supplied by the computer program, between the two side-by-side decks. In the figures the bottom part of each deck is partially missing owing to photographic problems. The full decks were displayed as MC paintings on the TV screen.

We do not need to give special MC paintings illustrating their utility in teaching computer science because the production of each painting or mathematical exercise illustrates many aspects of the computer's operation and of the programs controlling it and of transmission of information from and to the computer and its peripheral equipment, including the TV screen. One can, however, visualize specialized computer programs that would produce animated illustrations for the computer science student, on the color TV screen, of such concepts as loops, binary and hexidecimal arithmetic, algorithms for calculations and control, and structured programming. In fact, the computer science student will more often find topics related to the operations producing a painting than to the final product, the MC painting itself. For example, changes in one part of the computer memory, however arrived at, produce corresponding changes on the color TV screen, so beginning program users could see the location and aspects of execution of their programs. They could also see other computer processes: binary switches that have many uses in any computer; closed sub-routines that are used to perform specific tasks for the user of MC painting; and how motion of the joystick is converted to motion of color spots on the screen through so-called analog to digital (A/D) conversion.

The art student gains experience and understanding both in using the MC painting medium and in studying finished paintings. He can translate his aesthetic choices into a product, in this medium of the future, produced in conjunction with the computer by his hand, eye, and imagination.

The following MC painting tools are important to each teaching area:

a) The ability to add, remove or move "spots of color" where one wishes. This permits counting; illustrates (in its computer programs) branching and logical decision-making; and is the tool by which the picture can be assembled or modified.

b) The method of application of this "spot of color" makes you think about plotting the position and plotting the color as you construct a shape. You can see, for example, the distinction between (i) a set of spots considered without regard to their color or shape; (ii) subsets that form a recognizable pattern without regard to color; and (iii) smaller subsets that contain elements in a given pattern and are all of the same color. The mathematics and computer science students can use these as intriguing examples of sets, subsets, operations on sets and Venn diagrams that portray logical relationships. And the art student, though not necessarily using these mathematical concepts consciously, nevertheless can see the entities of pattern, density and contrast.

4. How MC Painting is Done*

Our discussion here of MC painting illustrates our general remarks about what computers can do when properly programmed.

The equipment: The MC paint brush can paint 15 or 16 different colors on the color TV screen.** The color appears in small squares, 64 from side to side and 64 up and down. You saw in Section 3 some black and white versions of the color pictures made with this brush. The painting is done by moving

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*The MC painting medium is described in some detail in Reference 5. A general discussion of the development of the microcomputer system ("MSEA"), part of which supports the MC painting, is given in Reference 6.

We recognize that several tools in the MC painting medium could be made more powerful or more easily used by modifying the equipment or the programs. These many modifications are not discussed in this paper, but some of them have been mentioned in Reference 5. Automatic generation of lines and a generalized block printing are two modifications that have already been implemented.

**MC painting can be done with a black and white TV. The cost of the equipment is much less, but much of the value of the painting is lost when not in color.

a "joystick"* which moves the "brush" across the color TV screen. You do not see a real brush. Instead as you move the joystick the computer puts color on the screen as though you were painting a dab or stroke of color on the TV screen with a brush.

The process: Four "brush strokes" are available, differing in shape and size. Color can be "picked up on the brush" from a "palette" shown on the color TV screen, or from any previously painted spot on the screen. By pushing one button you tell the computer to paint or to move the brush without marking the screen. Another button lets you pick up color on the brush from the "palette" or other color spots on the screen. A third button lets you choose one of the fifteen colors for the ground color. And the two switches give you those four different brush strokes mentioned above.

Using a keyboard like a typewriter keyboard** you can tell the computer to store a color picture by name. The picture you've painted on the color TV screen can be saved on a cassette tape or a so-called floppy disk. You then can recall any picture that has been saved. Photographs of the TV screen (with red filters) yield good color prints or slides, or you can ask for a printed, black and white representation of your color picture. This version of the picture is typed out rapidly and automatically, each color represented by its own code (zero = black; 1 = dull red, F = bright white, etc.).

The color-coded, printed version *** of Figure 2 is shown in Figure 6. It should be clear that MC painting and traditional painting (with brush and water color, for example) have different but overlapping characteristics and applications. Each medium has capabilities not possessed by the other. We feel that

*Like a small version of the joystick of an airplane in the 1920's.

**A keyboard is also an alternative to buttons and switches for controlling the operations in MC painting.

***The printer output elongates the picture from top to bottom.

the MC painting we have outlined here will be found to be an integrating and innovative educational medium that is easy to use in many subjects of study.

5. What the Computer is Doing in MC Painting

These various tasks that the computer does for you in the MC painting (typed commands, pushed buttons or movement of the joystick) are implemented on the computer by computer programs that can be run on many different microcomputers. (See References 5 and 6 for more details.) The tasks illustrate the variety and power of a computer, suitably programmed, to serve the teacher or student in the arts as well as in other fields.

What is the computer doing inside as it lets you "paint" on the TV screen? As said before it is following instructions in the computer program. What are some of these instructions for the computer? Let's consider a few examples (not a complete list):

a) store (in the computer "memory") a number or a letter or a word that you type at the keyboard.

b) plant a color spot on the screen (after sensing what color is "on the brush" and where the brush is).

c) print a number (the code of a color of one spot on the picture) and do this automatically for the whole picture.

d) calculate where each part of a wide brush will paint on the screen.

e) modify the picture according to some rule given (programmed) by the teacher or the student.

In summary, (a) a computer easily senses a button, a switch position a joystick position or typed numbers or word commands, i.e., it inputs of information from the user; (b) it processes the information it has in its memory (changes the information, makes calculations, searches, sorts, etc.);

(c) it puts a number, a word or a color spot on the TV screens, it prints information or it turns a light on or off (i.e., it outputs information to the user).

6. A Computer in my School?

The school computer is, by definition (Section 2), easy to use, widely useful and inexpensive. But you will say, and rightly, "These characteristics alone will not move a school computer into my classroom. I know little about them. Aren't computers used just by administration?"

We can begin to answer these questions though the paths taken to acquire a computer will vary for different schools. The directions are those which involve and challenge the students and which directly aid the teachers.

We note first that computer-based simulations constitute a powerful instructional facility in a great variety of subjects (Reference 7). MC painting is an art and instructional medium in its own right, but it can also support simulations because of its highly interactive nature. We note further that any display done with MC painting by any teacher or student is art by the very nature because of its form and color, and the art becomes exciting and real just by the fact that it is produced on the screen under the immediate control of the user.

The challenges to the students are based on their experience in using the MC painting. Mathematics students, for example, can use the system for illustrating such concepts as sets and operations on sets, coordinate geometry and mappings and others we have discussed earlier. (They can even store their MC mathematics paintings if these are needed for further study and modification or to show their friends.)

A sample challenge for these mathematics students is this:

> Specify a new algorithm for a set operation, a curve to be plotted or a mapping to be made. Discuss with a student programmer this specification so that he can design the program that will create this new MC painting tool for students and teachers.

A corresponding challenge for the computer science students is:

> Discuss the mathematics student's specifications with him; point out what can be done easily, what can only be done with difficulty and what, in view of the resources available, may not be possible: agree on a revised specification; program to this specification; and demonstrate the program to the mathematics student. (Of course a computer science student may be the one to bring a problem to the mathematics student.)

Art education students can use MC painting for creating their art work, for studying the aesthetic elements of their paintings, storing and perhaps photographing them, and sharing them with their friends. A sample challenge for these art students is:

> Take a specific capability of the MC painting (say one of the four brush strokes); plot and replot a design to discover and learn the possible visual effects of this one type of "brush stroke." The art student can share his visual understanding with the mathematics or computer science students to enhance their understanding of the medium.

These joint undertakings give each student valuable experience both in his own field and in cooperation among people of different skills and backgrounds in order to reach a common goal. Thus, there develops a community of interest and a broadening of the appreciation, by each student, of the whole range of man's intellectual and creative endeavor. And each student can be given recognition in the school for his contribution to the MC painting and its uses. (See References 3 and 4).

Teamwork is thus necessary as well as advantageous between students in any two fields of study. It will have special usefulness in those schools where it brings the art student together with the mathematics or computer

science students; for until some years from now it is unlikely that many art students and teachers can do computer programming or that many mathematics and computer science students have experienced the challenge and beauty of artistic creativity. The teamwork can relieve this isolation by using the MC painting as a medium that becomes fascinating and instructive to both teacher and student as they begin to acquire computer literacy and later apply computers in any area of study.

If some students are involved both in mathematics and computer science study, or the same teacher teaches both subjects, then the multi-purpose uses of MC painting will come about even more readily. We would hope that some mathematics or computer science students will learn of the attractivness and relevance of art to them through their use of MC painting in their own fields. It is also possible that art teachers will get interested in programming. This has happened already, to a small extent, even before microcomputers came into the schools and before there was such a powerful easy-to-use artistic medium available as the MC painting.

We have discussed the worthwhile challenges to students that MC painting affords. That the teacher is aided follows at once from the fact that the students are stimulated in their learning activities and some of the students become resource people for the teachers and for the other students.* And finally everyone develops several kinds of "literacy."

7. Literacy-in Mathematics, Computers or Art

Literacy, as we are using the term here, is a metaphor. We mean literacy to imply understanding, (intuitive or reasoned) in a subject area

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*In fact students can become the largest resource for on-going and imaginative development and use of school computers, in all fields of study (See References 3 and 4).

and an appreciation of the place of this subject in the life of oneself and the lives of others.

Like the other literacies, mathematics literacy can be defined at many levels. Here we'll say that a student possesses mathematics literacy when he can feel confident in using his mathematics skills in his school-home-community environment.

Computer literacy implies knowledge of "what computers can do for and to me." I want the computer to do things for me, and I dislike (want to avoid) their doing things to me. Students of today will have to be literate with computers tomorrow. "Hands-on" experience with the easy-to-use school computer can lead most directly to computer literacy.

Literacy in art implies some understanding and some appreciation of "what I like (or others like) because it's aesthetic", i.e., literacy here involves making aesthetic judgments both as creator and observer.

Very often the art student will not have computer literacy,* and the mathematics and computer science students will often not have art literacy (though parts of artistic experience are relevant to the teaching of mathematics and computer science by MC painting.)

It is perhaps surprising, but it is also exhilerating to realize that MC painting promises to narrow this literacy gap among students in the three areas.

MC painting humanizes the computer for everyone. It is a medium and a set of tools that "I control", that allows me to release my spontaneous questioning and creativity in mathematics and computer science as well as in art. (It is worth noting that, in institutions as different as schools

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*Artists have, however, explored and used new technology over the centuries.

and prisons, discipline problems (coming from boredom, loss of freedoms and lost identity, for example) have been reduced when art instruction and art activities are made available.) As one teacher said, "A big attraction of MC painting is that you start from scratch, you can be truly creative, rather than just 'painting-by-the-numbers' or following some other cookbook recipe."

Let us consider again how a beginning student may use the MC painting described in Section 4. A student finds very quickly that he can easily control the computer and produce pictures that demonstrate his ideas and express his inquiries and his imagination whether in mathematics, computer science or art. He is telling the computer what to do in such a natural way that he can forget it (if he wishes to) and concentrate on his uses of the computer, whether intuitive, expressive or calculated. He has therefore found that he can work with a computer system and is prepared to learn about other computer services. He has gained a large measure of computer literacy, and at a level corresponding to his own background in computers.

As we suggested earlier, the art student might say "How about a wider brush" or "a different presentation of the pallette" or he may want to experiment with changing every bright red spot to a dull red spot.... He will then specify for a computer science or mathematics student what he wishes a new computer program to achieve in his MC painting. This results in students learning very specific examples of the relationship among art, mathematics and computer science; they are also gaining literacy in these fields, again, at levels appropriate to their experience and needs.

Let's give a few more examples. The art student (actually, any student) will find that the colored pictures he produces can be a source of keen

enjoyment, but he will probably also start asking himself questions that lead directly to the mathematics or computer science aspects of the MC painting and the programs that make it possible. Some elementary examples: "Why 64x64 squares on the screen?" "Why 15 colors?" "How does the computer 'know' when I am ready to paint a dab of color (or pick up a color on the brush) and where I want to do that?" "What makes the picture symmetrical?"..., and there may well be many deeper questions. The answers, at the appropriate level, lead to greater understanding of the mathematics and computer science inherent in the program and in the operation of the computer equipment, and also to greater appreciation and understanding of the aesthetic qualities inherent in the MC painting medium itself.

We note that design, composition and structure, which MC painting illustrates, are topics of interest in all three areas. One of the many examples: the design elements that are natural and easy to form in MC painting have been used effectively both by naive early American designers and craftsmen and by modern American artists who are "international sophisticates" (Reference 8).

But may the computer science or mathematics student (or any other non-art student) also become interested in the artistic creativity made possible by the MC painting? This is harder for us to answer than the earlier questions we have posed. How many mathematics or computer science students have had exposure to painting with brush and canvas? We do know for sure that mathematics and computer science students will find MC painting to be an attractive introduction to art.

Whatever the field of study, exposure and interaction are the first steps toward interest and literacy, and such interaction is easy and exciting with MC painting as the medium.

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